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MEASURING THE IMPACT OF NASA
ON THE NATION'S ECONOMYNASA Office of Special Studies
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P-12Summary:

A review of efforts to measure the economic impact of NASA's programs provides the following findings:

- o Because of the small size of NASA spending for R&D relative to total U.S. R&D, and because of difficulties inherent in quantifying either the costs or benefits of R&D, single number claims (e.g., "7 to 1") of the economic payoff of NASA R&D can be easily assailed.
- o More persuasive are estimates of concrete gains of generally acknowledged social or economic value that have resulted from particular NASA-stimulated products or processes. Further technology transfer studies which carefully examine process as well as cost/benefits would contribute to such estimates.
- o One of NASA's greatest impacts, relative to the size of its budget, may be the stimulus it provides to the U.S. scientific and technical workforce.
- o NASA has contributed measurably to the economic viability of several regions and many communities.

"Return on Investment": How Valid are the Numbers?

Past efforts to quantify the economic benefits of the civilian space program (for which R&D has been the principal "cost") fall into three loose categories: macroeconomic analyses, microeconomic analyses, and technology transfer studies.¹ Claims that civilian space R&D returns a given number of dollars for each dollar spent are usually based on the Midwest Research Institute (MRI) study conducted in 1971² (the MRI study was updated in 1988), the Chase Econometric Associates study conducted in 1975 and 1980,³ and a 1978 study by the European Space Agency (ESA)⁴ of the economic benefits of its contracts.

In the MRI study, investigators subtracted from total national productivity changes in the economy between 1959 and 1969 those attributable directly to capital and labor. They then attributed the "residual" changes to R&D, after taking into account changes in demography, education, health, work-week length, and economies of scale. Segregating that portion of total (Federal and private) R&D outlays attributable to NASA outlays, the group estimated that the discounted rate of return on NASA R&D investment for the period 1959 to 1987 would be 33 percent, or an overall return of 7 to 1. Critics of the study point to several questionable assumptions. One is that NASA R&D is, for purpose of

measurement, similar to all other R&D. The other is that the benefits of R&D have a fixed lifetime in the economy of 18 years.⁵ The MRI study also overlooks Federal contributions to the Nation's infrastructure, e.g., the highway system.

The Chase study employed an estimated production function for the U.S. based on a potential GNP for a 15-year time series.⁶ Chase then calculated the variations in the potential GNP that could not be accounted for by capital and labor inputs, which it treated as the "residual"; this residual, in turn, was broken down into independently variable components, viz., NASA R&D, other R&D, industry mix, capacity utilization ratios, and demographic factors. Chase also incorporated within its model lag functions to account for the delay between R&D outlays and the development of new technologies. Using the resulting equations, Chase calculated the cumulative "productivity" return of NASA R&D as 14 to 1, or an annual discounted rate of return of 43 percent to NASA R&D outlays. A 1977 review of the Chase study conducted by the U.S. General Accounting Office at the request of Senator William Proxmire concluded that, largely because of instability in the equations used by the Chase study, it could not confirm its conclusions.⁷

In 1980, the U.S. Department of Labor, Bureau of Labor Statistics (BLS), at NASA's request attempted to measure the effect of NASA expenditures on productivity changes at the industry level for industries connected to aerospace production.⁸ The aim of the study was to aggregate benefits from NASA expenditures upon the economy at a level between individual products or firms and the GNP. Because of statistical variability, the BLS was unable to make more than very tentative findings. These included verification of the general assumption that technological advances tend to be labor-saving; that the R&D component of technological change has tended to save capital; and that the returns to private R&D investments tend to be between 15 and 30 percent, while Government returns from R&D were between zero and 5 percent. BLS equations did not show a consistent pattern of returns from NASA R&D, which the BLS attributed to uncertainties in several of the variables used.

Alternative approaches to measuring economic impact include the survey approach taken by the European Space Agency in its own 1978 and 1980 attempts to measure the economic impact of ESA funding on its contractors. The study's investigators conducted extensive interviews with 80 percent of ESA's contractors to identify benefits in four major categories: technological advantages, commercial advantages, advantages for organization and methods, and increased labor productivity. The results were aggregated by industrial sector. When a cost/benefit ratio was developed for overall return, the study concluded that, from 1960 through 1980, the return on ESA contracts was 2.7 to 1. The usefulness of this single number measurement was, however, limited by the fact that many macroeconomic and competitive factors were not included in the analysis.

Roughly 75-80 percent of NASA's budget is typically allocated for R&D. The question of NASA's impact on the economy is thus inseparable from the question of the economic value of Federally funded R&D in general. Of the \$52 billion in Federal obligations for R&D for FY 1985, for example, only 6 percent represented NASA R&D obligations.⁹ In 1986, the U.S. Congress's Office of Technology Assessment (OTA) examined our ability to measure the economic returns on Federal funding for R&D and reached the following conclusions:

... the metaphor of research funding as an investment, while valid conceptually, does not provide a useful practical guide to improving Federal research decision-making. The factors that need to be taken into account in research planning, budgeting, resource allocation, and evaluation are too complex and subjective; the payoffs too diverse and incommensurable; and the institutional barriers too formidable to allow quantitative models to take the place of mature, informed judgment.¹⁰

The OTA study found that in the private sector little reliance is placed on quantitative techniques for making R&D allocation decisions. Neither Return on Investment (ROI) models nor "Business Opportunity" calculations (which depend upon accurate estimates of future sales and product development time)¹¹ have been found to be as useful as experienced, subjective judgment ("common sense") and a good, ongoing information and communications process among research, development, and marketing staffs.

Henry R. Hertzfeld, an economist employed with NASA between 1977 and 1983, has examined extensively the problem of establishing economic returns on the Nation's civilian space program. He concludes:

First, no economic study should attempt to put a "bottom-line" ratio or return on space R&D investments. . . . All such numbers that have been used as representative of a total return to space R&D actually have measured partial returns. And, all such numbers are products of economic models with many limiting assumptions. Even when these assumptions and qualifications have been laid out carefully, the existence of the number is an attractive bait to those politicians and others who need to justify space R&D. Once a "total" returns number is used, it finds its way into misuse quickly.

Second, studies that contrast the returns from Government space R&D with the returns from private R&D should be avoided. There is no a priori reason why Government R&D must have a measurable GNP or productivity return. For technical measurement reasons--such as the fact that Government accounting standards treat all Government expenditures, including R&D, as current spending with no imputed investment returns--the measured returns to Government R&D should be smaller than those to private R&D. And, for the obvious reason that investment of Federal funds for R&D is undertaken because of a national-mission-oriented need not translatable directly into economic profits, the returns may not be picked up by standard economic measures. Therefore, it is of no surprise that comparative studies show returns to Government R&D hovering around 5 percent and those of private R&D at nearly 40 percent.

Third, studies that have poorly defined objectives are particularly susceptible to error when dealing with R&D. Since R&D is a very general term, encompassing many different activities, the evaluation models frequently may not fit the questions being asked. Research activities produce knowledge, while

development is aimed at useful end products. A process-related improvement may occur quickly and be hidden from direct measurement, while a new product that is easier to observe and measure may take a long time to reach a market and be diffused through the economy. Different economic models and data have to be used in each case. . . . Since almost all space R&D is Government-supported, the traditional economic models built on the operating assumption of a freely competitive market must be modified. In current practice, this is rarely done. . . .

The most promising type of economic study for measuring returns to space R&D is the documentation of actual cases, based on surveys of the agencies, companies, and users involved directly with the space technologies. Such studies provide one way that specific economic questions can be formulated and answered with relative clarity. . . .¹²

Economic Impacts: Technologies and Communities

A more meaningful approach to measuring NASA's economic impact is suggested by benefit/cost analyses for individual products or processes. Typically case studies, these analyses may include qualitative factors. The appeal of benefit/cost studies is that they are relatively empirical and concrete in nature. However, they too have limitations. Usually only successes are studied, and indeed often only successes leave the kind of data trail necessary to do a benefit/cost analysis. Other difficulties are selecting the appropriate discount rate and a representative period of time for measuring benefits, and allocating the costs of developing a new technology when those costs are distributed among both private and public sector organizations.

These difficulties were illustrated in the 1975 study done by Mathematica, Inc.¹³ Mathematica attempted to identify the return from four technologies that NASA had a significant role in developing: cryogenic insulation, integrated circuits, gas turbine engines, and NASTRAN (a computer program for analyzing structural properties of large vehicles). Mathematica did not attempt to measure the costs of developing these technologies. Rather, it attempted to measure the benefits of the new commodity and the associated decrease in the costs of production. Mathematica concluded that, from 1975 to 1984, the four technologies should return a discounted total of \$7 billion (constant 1975 dollars) in benefits attributable to NASA's role in their development.¹⁴

The importance of some "big technologies" resulting directly or indirectly from space R&D is clear: satellite communications, weather and remote sensing satellites, and new materials such as carbon/graphite composites. Public access to telecommunications has increased exponentially during the last two decades, and its cost per unit service has shrunk as its volume has grown. Measuring the benefits of weather and remote sensing satellites has proven more complicated because of the difficulty of calculating the impact of improved weather information on final costs, given the speculative crop futures markets. Attempting to measure the benefit/costs for such technologies as satellite-borne

navigational aids or search and rescue instruments is a reminder that not all values can be quantified.

A relatively small portion of NASA's R&D budget has been dedicated to the aeronautical research which was its predecessor's principal mission. From 1945 to 1982, the National Advisory Committee for Aeronautics (NACA) and NASA accounted for \$9 billion (or 8 percent) of the \$108 billion spent on aircraft R&D.¹⁵ Using as the common index of commercial aircraft performance the number of available seats multiplied by the cruising speed and the direct operating costs per available seat mile, the progression from the DC-3 to the Boeing 707, and from the Boeing 707 to the Boeing 747, has been estimated as resulting in \$18.2 billion (1972 dollars) in additional air transportation services supplied for the actual amount paid.¹⁶ Assuming \$108 billion as the cost of improving aircraft technology over the period 1945-1982, and \$18 billion the benefit, the "return" can be calculated as roughly 17 percent per year. The return is even larger (about 27 percent per year) if military aviation R&D costs are subtracted from the cost side.¹⁷

Since the mid-1960's, NASA has had a technology transfer ("technology utilization") program to promote the adoption of aerospace technology for nonspace uses. In 1977, NASA asked Mathtech, Inc., to conduct a benefit/cost analysis of nine innovations transferred from NASA to the private sector: the cardiac pacemaker, laser cataract tool, human tissue stimulator, meal systems, nickel-zinc battery, zinc-rich coatings, track-train dynamics, and a firefighter's breathing system. The benefit/cost ratios for these innovations varied widely, from the 4-1 ratio for the cardiac pacemaker to the 340-1 ratio for zinc-rich coatings. Variations were due to a combination of factors, e.g., readiness for a commercial market and the difficulty of quantifying noneconomic benefits, which are most apparent in the biomedical field.

The NASA budget is only a small portion of the Federal budget; measured against the Nation's GNP, it is minuscule. Given this fact, and the uncertainties of attempting to measure the benefits of R&D, the economic impact of the civilian space program is probably best assessed in terms of specific industries, products or processes, and the economic health of individual communities and regions. The entry of a new employer, or expansion of an existing employer, in a community or region has a multiplier effect on that community's economy. The tax base increases, social services can expand, and, in the case of an employer like NASA with its requirement for highly skilled labor, local and regional education will be stimulated. All of these effects can be measured and, at least in the case of Houston, Texas, and Huntsville, Alabama, they have been.¹⁸

The importance of NASA to the local economies surrounding its field installations in Alabama, Mississippi, Florida, Texas, Maryland, Virginia, Ohio, and California is well known. What is less widely appreciated is that the civilian space program has, since the first "push" of the Apollo program, substantially increased the amount of money it has pumped into regional economies around the country. In any given year, NASA has spent 80-90 percent of its allocations on contracts with private sector firms, thus fostering local and regional industry as well as fostering the development of a technically trained labor force throughout the country.

Between 1961 and 1989, the number of states receiving NASA prime contract awards increased from 36 to 47, while the dollar value of these contracts (after adjustment for inflation)¹⁹ increased by a factor of at least 2 in every region of the country except the Great Lakes and Plains states. In the Rocky Mountain states, their value increased by a factor of 38; in the Far West, a factor of 3; in the Southwest, a factor of 14.5, and in the Southeast, a factor of 9. Some of the most dramatic increases have occurred in the non-Sunbelt states of Idaho (x296), Wisconsin (x11.2), New Hampshire (x54) and Vermont (x83).²⁰ Not all infusions of Federal funds into communities and regions are the same; any multiplication of NASA dollars occurs overwhelmingly in the private sector, and among industries engaged in advanced technology products and services, or among those that support them.

Education: Investing in Human Capital

Economic and social interests converge when the public subsidizes education. Since the late 19th century, few have questioned that the public should support the education of its young people. The predominant rationale for public education throughout much of the intervening period was socialization of the young (especially immigrants) and upward mobility. In recent years, public concern over the role of education in securing this country's economic competitiveness in the world economy has become more widespread.

The purposes of education considered as an investment in human capital are often confused. For example, is our goal more persons with graduate degrees in science and engineering (who are statistically most likely to teach, and thus produce more persons with graduate degrees in science and engineering), or skilled technicians capable of reading sophisticated instruction manuals? Assuming that activities to motivate children toward science and engineering careers could be proven effective, will not opportunity and the labor market have as much or more to do with their ultimate careers? Other than statistical correlations, can any causal connection be proven between money spent and educational outcome obtained?

Direct post-World War II Federal Aid for post-secondary education²¹ has taken three generic forms: (1) student financial aid programs, including the National Defense Education Act (NDEA) Student Loan program, (2) grants awarded by the National Science Foundation (NSF) and the National Endowment for the Humanities (NEH), and (3) student financial aid to veterans (GI Bill and Korean and Vietnam War counterparts). Of these three types, the first and third are not discipline-specific. All three, in varying degrees, respond to the policy goals of increased access, increased choice (among institutions), and increased quality. The NDEA Student Loan Program (Title II), created in 1958 in the wake of the Sputnik crisis, is distinctive in that while it was an attempt to respond to all three policy concerns, it placed special emphasis on improving the scientific and technical "pipeline."

In 1972, the National Defense Student Loan Program was changed to the National Direct Student Loan Program; in 1987, the Congress replaced it with the Perkins Loan program.²² Requirements for the current (Perkins Loan) program reflect a significant change in emphasis from the pre-1972 loan program. Emphasis on science and related fields, as well as a national proficiency in modern foreign languages, abandoned in 1964, has not reappeared. Of equal importance, the original policy of enabling promising students to advance educationally without regard to financial means has been replaced by a program designed "to be a credit assistance program authorized by Federal law for the benefit of an economically disadvantaged class of person. . . ." This trend is clearly reflected in the program's funding history. In 1965, the NDSL program commanded 68 percent of the total Federal student financial aid appropriations for the year. By 1986 (the NDSL program's final year), after the addition of the Educational Opportunity Grants and Guaranteed Student Loan program (1966) and the Pell and Supplemental Educational Opportunity grant programs (1973) to the Federal constellation of student assistance programs, the NDSL program received only 2 percent of the \$7.9 billion allocated for Federal student financial assistance.²³

Useful measures of the impact of Federal funding for post-secondary education on the particular policy goals for which it was intended are scarce, except in the case of the National Science Foundation (NSF). "Outcomes" data from NSF for the NSF graduate fellows program²⁴ suggests that when a student assistance program is targeted at a population that has an existing career motivation and ability, that program is likely to be effective. The NSF's Graduate Fellowship Program has been the largest of the Foundation's several fellowship programs. Fellowships are awarded on a highly selective basis of ability rather than "need." Below are some of the measurable outcomes of the program for the period 1952-1976:

- o NSF Graduate Fellows obtained their doctorates in 25-30 percent less time than typical Ph.D.'s for the same field, sex, and graduation cohort.
- o 30 percent more NSF graduate fellowship recipients planned postdoctoral study than Ph.D.'s in general.
- o About two-thirds of former NSF Fellows who had attained doctorates were employed in institutions of higher education.
- o In one of the few objective measures of "innovativeness" or contributions to advancing research, NSF graduate fellows (1952-72) published nearly 40 percent more than the average of all science Ph.D.'s, and are cited more than twice as often.

NASA's Investment in Education

While NASA's share of the entire Federal R&D budget has been small, its investment in higher education in scientific and technical fields has been large relative to comparable

investments being made elsewhere in the Federal Government. For example, in 1965, when the agency enjoyed its first and last +\$5 billion budget until 1980, NASA allocated \$46 million for its Sustaining University Program, as well as an additional \$165 million for research grants and contracts to universities (not including the Jet Propulsion Laboratory of the California Institute of Technology). The total of these amounts, or \$211 million, amounted to 86 percent of all 1965 non-NASA Federal appropriations for student financial aid for that year.

During its first three decades, NASA has invested in scientific and technical education at all levels. Curriculum and teaching enhancement activities for elementary schools and high schools, supplemental training in science and technical subjects for college teachers, co-operative education work-study programs, and university grants and assistantships are the principal means by which NASA has sought to promote the continuing replenishment of the country's scientific and technical labor force. Longitudinal data to measure the effectiveness of elementary and secondary school programs are unavailable. However, NASA education program personnel routinely conduct participant survey evaluations of their programs which provide a basis for subsequent program planning. The extent to which quantifiable goals (e.g., increase in number of participants or percentage of minorities) are met is also routinely measured.

Through its cooperative education program, NASA has enabled entry-level employees to complete undergraduate degrees while acquiring work experience, not only in science, engineering and technology, but also, to a lesser extent, in management and business administration. Participants in NASA's cooperative education program are civil service employees (largely at NASA's field installations). In FY 1982, NASA cooperative education students were enrolled in 100 colleges and universities in 30 states and the District of Columbia. During the past 5 years (1985-1989), the percentage of NASA "co-op" program graduates who remain with NASA as permanent employees has ranged from 59 to 72 percent. The program also appears to be providing the secondary benefit of increasing the proportion of minorities and non-minority females in the NASA workforce.²⁵

NASA also awarded three-year predoctoral traineeships as part of its Sustaining University Program established in the early 1960's to replenish the supply of scientists and engineers being recruited for the Apollo program.²⁶ The career patterns of 4,055 recipients from 151 universities of NASA graduate traineeships during 1960-1973 who received the Ph.D. were recently examined in a NASA-funded study.²⁷ Of the 4,035 Ph.D. recipients, 55 percent received their doctorates in physical sciences, 32 percent in engineering, 10 percent in the life sciences, and 32 percent in the social sciences. Only 21.5 percent have been working in space-related fields for any length of time, and only 13.8 percent work for Federal, State, or local government. Thus, the principal beneficiaries of NASA's graduate traineeship program have been the private sector and academia. NASA predoctoral trainees as a group have been awarded over 4800 patents and published about 1600 books and over 76,000 technical reports--an additional indication of the program's contribution to the Nation's technical resources.

A more recent variant of the graduate education support provided under the Sustaining University Program is NASA's Graduate Student Researchers Program, created in 1980. About 800 students have completed the program, which currently awards grants of up to \$18,000 per year (renewable for 3 years) based on "competitive evaluations of academic qualifications, [the] proposed research plan," and the benefit recipients are likely to receive from use of NASA research facilities. About half of each year's awards are given to students who are working in disciplines of interest to NASA's research centers and planning to make substantial use of those centers' facilities.²⁸

Conclusion

In the arena of public policy, "good" policy is ultimately a subjective matter, and progress comes most often in small, intuitively right steps. The measurement of economic benefits of Federal spending of any kind is so imperfect a science that common experience may be a better guide.²⁹ Indeed, the premise that Federal spending should be held to a market sector standard of accountability may be wholly inappropriate. The public spends money on many activities precisely because they have been found insufficiently profitable to interest the private sector, but are otherwise socially compelling and thus become a part of the Nation's political agenda.³⁰ Like all Federal programs, the civilian space program depends on a widespread public conviction that our common experience as a Nation and world community, now and in the future, will be the richer for it.

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* Please let us know of any factual errors; telephone (202) 453-8766.

FOOTNOTES

1. Macroeconomic modeling to estimate long-term effects of R&D on aggregate economic indicators such as gross national product (GNP), employment, and inflation; microeconomic modeling to measure the cost/benefit ratios for particular inventions or innovations; and efforts to measure the rate of, and savings from, the transfer of technology from Federal space R&D to the private sector through technology utilization programs, patent licensing, and patent waiver programs. Henry R. Hertzfeld, "Measuring the Economic Impact of Federal Research and Development Investment in Civilian Space Activities." Unpublished MSS. pp. 261-300. (NASA Historical Documents Collection, hereinafter cited as NHDC)
2. Economic Impact of Stimulated Technological Activity. Midwest Research Institute, November 1971. Prepared under NASA contract NASW-2030.
3. David M. Cross. The Economic Impact of NASA R&D Spending, An Update. Philadelphia: Chase Econometric Associates, March 1980. Prepared under NASA contract NASW-3345.
4. F. P. Fitussi, Economic Benefits of ESA Contracts. Paris: European Space Agency, July 1978; Goetz Niederau, Economic Benefits of ESA Contracts. Paris: European Space Agency, 1980.
5. Hertzfeld, "Measuring the Economic Impact of Federal Research and Development...", Ibid.
6. The potential GNP is an estimate of what the GNP would be if full employment existed.
7. U.S. Congress, General Accounting Office. "NASA Report May Overstate the Benefits of Research and Development Spending." Report of the Comptroller General, PAD-78-18. (October 1977).
8. Impact of Government and Private R&D Spending on Factor Productivity in Space Manufacturing. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, July 1980. Prepared under NASA grant W-14539.
9. In this fairly typical year, Defense R&D accounted for 66%, Energy R&D accounted for 11%, and Health and Human Services R&D for 9%. NASA thus ranked fourth among the top four Federal supporters of R&D. "Research Funding as an Investment: Can We Measure the Returns?" Science Policy Study, Background Report No. 12. Office of Technology Assessment (Washington, D.C.: December, 1986).
10. Ibid., p. 9.
11. These methods are described in "Research Funding as an Investment," Ibid., pp. 52-54.
12. Hertzfeld, pp. 291-293.
13. Quantifying the Benefits to the National Economy from Secondary Applications of NASA Technology. NASA CR-2674. Princeton: Mathematica, Inc.
14. NASA's entire budget outlay for 1975 was \$3.2 billion.
15. The NACA was incorporated into NASA when the aerospace agency was created in 1958. During the period 1945 to 1982, the military provided \$77 billion (71%) while industry provided \$17.4 billion (16%). "Research Funding As An Investment: Can We Measure the Returns?" Science Policy Study Background Report No. 12. Office of Technology Assessment (Washington, D.C.: December, 1986), p. 18.

16. Ibid., pp. 18-19. This calculation does not, of course, take into account possible consumer choice of alternate forms of transportation or to reduce travel had air transportation costs not been reduced. Nor does it take into account economic benefits of reduced travel time, an expanded aircraft industry, or increased foreign sales of U.S. aircraft.

17. Ibid., p. 20.

18. Economic Impact of the Manned Space Flight Program, NASA Office of Space Flight (April 1967), pp. 54-256; Loyd S. Swenson, Jr., "The Fertile Crescent: The South's Role in the National Space Program," Southwestern Historical Quarterly, Vol. 61, No. 3 (January 1968); Johanna Shields, Andrew Dunar, and Stephen Waring. History of Marshall Space Flight Center. Unpublished manuscript in progress. (July 1990), Chapter III, NHDC.

19. Excludes procurements of \$25,000 or less; also excludes awards placed through other government agencies, awards outside the U.S., and awards on Jet Propulsion Laboratory contracts.

20. NASA Historical Data Book, Vol. I. NASA SP-4012. (Washington, D.C.: National Aeronautics and Space Administration, 1988). U.S. regions are defined as: Far West - California, Nevada, Oregon, Washington; Rocky Mountain - Colorado, Idaho, Montana, Utah, Wyoming; Southwest - Arizona, New Mexico, Oklahoma, Texas; Plains - Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota; Great Lakes - Illinois, Indiana, Michigan, Ohio, Wisconsin; Southeast - Arkansas, Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia; Mid East - Delaware, Maryland, New Jersey, New York, Pennsylvania; New England - Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.

21. As distinguished from indirect aid via. grants and contracts with institutions.

22. Named for the late Carl D. Perkins, former chairman of the House Education and Labor Committee. Depending on the period of initial commitment, loans in the current program (administered by the Department of Education) may be designated either "Perkins" loans or "direct" loans. The program now provides loans only for post-secondary or graduate education.

23. The Federal Student Financial Aid Handbook. Chapter Six: Perkins Loan Program (Washington, D.C.: U.S. Department of Education, Office of Student Financial Assistance, 1989-90), p.6-3. Susan H. Boren, "Student Financial Aid: Authorizations of Appropriations, Budget Requests, Enacted Appropriations and Outlays for Federal Student Financial Aid Programs FY 1965 Through FY 1990," CRS Report for Congress (The Library of Congress: Congressional Research Service, March 6, 1989).

24. Lindsey R. Harmon, "Career Achievements of NSF Graduate Fellows: The Awardees of 1952-1972." A Report to the National Science Foundation by the Commission on Human Resources, National Research Council. National Academy of Sciences, 1977. Joan Snyder, "Early Career Achievements of National science Foundation Graduate Fellows, 1967-1976." Office of Scientific and Engineering Personnel, National Research Council, 1988.

25. During 1987-1989 the percentage of NASA permanent hires from the "co-op" program in scientific and technical occupations who were minorities averaged between 16.6% and 19.2%, and in professional and administrative occupations, from 16.4% to 18%. The percentage of NASA permanent hires from the "co-op" program in scientific and technical occupations who were non-minority females averaged nearly 20%, and in professional and administrative occupations, from 43.3% to 53.7%. Data supplied by the NASA Office of Management, NASA Office of Personnel Management. See "The Civil Service Workforce," NASA Office of Management, Office of Personnel Management. (1987, 1988, 1989).

26. The approximate cost of each traineeship was \$20,000 in 1969 dollars. Data on the total number of traineeships awarded or the total cost of the program is at present not available. The traineeship program was halted in 1970 when it became apparent that the "pipeline" had become a logjam; by 1970, aerospace employment had dropped from around 420,000 to 200,000. Moreover, the Nixon administration decided that Federal support of graduate training should be the responsibility of the National Science Foundation or the Office of Education rather than a mission-oriented agency. F. B. Smith, "Detailed NASA University Program," Proceedings of the NASA University Conference, NASA (February 10, 1970). NASA History Division Historical Documents Collection.

27. "The Apollo Education Initiative: Origins, Activities, and Results," Space Policy Institute, George Washington University (June, 1990). Jeffrey D. Rosendhal and Thomas Dietz, "The NASA Predoctoral Trainees of the 1960's: Where Are They Now and What Are They Doing?" *Vugraphs*. (June 16, 1988). On file in the NASA History Division Documents Collection; Thomas Dietz, Laura Lund, and Jeffrey D. Rosendhal, "On the Origins of Scientists and Engineers," (April, 1989), NASA History Division Historical Documents Collection.

28. "Graduate Student Researchers Program, 1989/1990," National Aeronautics and Space Administration, Educational Affairs Division (1989).

29. For example, one analyst claims that there has been "no effect of government R&D' on productivity improvements in the airline industry." Common sense, which notes the expansion of the U.S. airline and aircraft industries since World War II, and finds the Boeing 747 a more productive aircraft than the DC-3, must suppose otherwise. Nestor E. Terleckyj, "Measuring Economic Effects of Federal R&D Expenditures: Recent History With Special Emphasis on Federal R&D Performed in Industry," paper presented to the National Academy of Sciences Workshop on "The Federal Role in Research and Development," Nov. 21-22, 1985. p. 6.

30. Indeed, Federal procurement policy since the 1950's has attempted to dissuade Government competition with the private sector.